The Optical Proper Motions of HH 7-11 and Cep E (HH 377)

Alberto Noriega-Crespo

SIRTF Science Center, California Institute of Technology

IPAC 100-22, Pasadena, California, 91125

Electronic mail: alberto@ipac.caltech.edu

and

Peter M. Garnavich

University of Notre Dame

Nieuwland Science Hall 213, Indiana, 46556

Electronic mail: pgarnavi@nd.edu

Received ______________________; accepted ______________________

ABSTRACT

A key ingredient in understanding the dynamics of stellar outflows is their proper motion. We have used optical images in the [SII] emission at 6717/31 Å and the red Digitized Palomar Observatory Sky Survey (DSS) plates to determine the proper motion of HH 7-11 system and the optical knot of Cep E (HH 377). The DSS plate measurements span nearly 37 years for both HH 7-11 and HH 377 and have wide field of view, which allows an accurate determination of the proper motions despite their relatively low angular resolution. The optical images, with higher angular resolution, cover a shorter period of 7 and 4 years, respectively, and have been used to complement the DSS measurements. From the DSS plates we have found that HH 377 has a proper motion of 0.031 ± 0.003 arcsec/yr with a PA = 206°, i. e. moving away from IRAS 230111+63, that at a distance of 730 pc corresponds to a tangential velocity of 107 ± 14 km s^{-1}. The values obtained from the optical images are consistent with these measurements. Similarly, the proper motions of HH 7 - 11 range from 0.015 ± 0.009 (HH 9) to 0.044 ± 0.007 (HH 11) arcsec/yr, and the flow is moving away from SVS 13 with a mean PA$\sim$ 136°. At a distance of 330 pc, these motions correspond to tangential velocities of $\sim 25 - 70$ km s^{-1}, i. e. comparable to the original values obtained by Herbig & Jones (1983). The measurements from the optical CCD [S II] images are again consistent with these motions, although in detail there are some difference, particularly for HH 7 and HH 10.

Subject headings: stars: ISM: Herbig-Haro objects — ISM: jets and outflows — ISM: kinematics and dynamics — stars: winds and outflows

1. Introduction

It has been nearly 20 years since the association between Herbig-Haro (HH) objects and bipolar jets from newly formed stars was established. A fundamental element for this conclusion was the determination of the proper motions of the HH 1/2 system, which showed atomic/ionic gas moving away in opposite directions from an embedded source at flow velocities of $\sim 300 - 450$ km s^{-1} (Herbig & Jones 1981; Pravdo et al. 1985). The fact that large format CCDs with small pixels have been around almost a decade has made it possible to measure relative proper motions more accurately, replacing the photographic methods. These relative proper motions measurements have been particularly successful for nearby Herbig-Haro outflows, where flow velocities of $\sim 100 - 400$ km s^{-1}, can produce measurable pixel shifts within 4-5 years for an object at a distance of $\sim 150 - 450$ pc, i.e. the distances to the Taurus and Orion molecular clouds, respectively. The method can be applied also on shorter time scales using high angular resolution HST images, as has been the case for HH 30 (Burrows et al. 1996) and HH 111 (Hartigan et al. 2001).

The results obtained by this method for objects such as HH 1/2 (Eislöffel, Mundt & Böhm 1994), HH 32 (Curiel et al. 1997), HH 34 (Eislöffel & Mundt 1994; Heathcote & Reipurth 1992; Devine et al. 1997), HH 46-47 (Eislöffel & Mundt 1994) and HH 110/111 (Reipurth, Raga & Heathcote 1996; Reipurth, Raga & Heathcote 1992) among others, have provided a unique picture of the dynamical behavior of these outflows. High angular resolution radio observations based on the same principle, have confirmed some of these results (e. g. for HH 1/2, Rodríguez et al. 1990) and given new measurements for systems such as HH 80-81 (Marti, Rodríguez & Reipurth 1998). The method is now being used in the near infrared, thanks to large format infrared arrays that allow to cover wider fields of view and include more reference stars. Objects like HH 1/2 (Noriega-Crespo et al. 1997, HH 46/47 (Micono et al. 1998), GGD 37 (Raines et al. 2000), HH 7-11 and 25/26 (Chrysostomou et al. 2000) and OMC-1 (Lee & Burton 2000), have proper motions measured either in H_2 2.12μm or [Fe II]

1.67μm. Nevertheless we believe that in some cases the smaller field of view and shorter time baseline provided by the IR arrays, make some of these results less conclusive than optical measurements.

The present work is motivated precisely by the difference between the optical and the near infrared measurements of the proper motions of HH 7-11. The tangential flow velocities of the atomic/ionic gas inferred by using the photographic plate method are $\sim 20 - 60$ km s^{-1} (Herbig & Jones 1983), while those of the molecular gas (H_2) determined by using the near infrared imaging method are $\sim 300 - 400$ km s^{-1}(Chrysostomou et al. 2000). This difference is difficult to explain from the theoretical point of view, since in other systems we observe quite similar velocities for both gas components (Noriega-Crespo et al. 1997; Micono et al. 1998). In the case of HH 7-11, the driving source SVS 13 is a relatively low mass proto-stellar object, that makes it even harder to explain the large H_2 proper motions (see S4).

Another goal of this project is to measure the proper motions of semi-embedded outflows. This is the case for HH 7-11, where the counter-flow is nearly invisible, and Cep E (HH 377), where most of the outflow is invisible at optical wavelengths (Ayala et al. 2000).

In this study we determine the proper motions of HH 7-11 and Cep E (HH 377), using digitized plates and optical CCD images. Both outflows are clearly seen in the Digitized Palomar Observatory Sky Survey[1] (DSS), first and second generation, and they provide a time baseline of nearly 37 years. The CCD images cover a period of 7 and 4 years respectively, with

[1]The Digitized Sky Surveys were produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.

the most recent images taken in Nov. 30, 2000 (see below).

2. Observations

The optical images were obtained with the Fred L. Whipple (FLWO) 1.2 m telescope and AndyCam CCD camera in 1993 on Oct. 12 (HH 7-11) and 1996 on Sep. 16 (Cep E). A narrow band filter centered at 672.5 nm and a width of 3.0 nm (FWHM) was used to isolate the [SII] emission. Second epoch images were taken with the 1.8 m Vatican Advanced Technology Telescope (VATT) and VATTCCD camera on 2000 Nov. 30. A similar narrow filter centered at 672.3 nm and 3.5 nm width was employed at the VATT. In all cases the CCD was binned by 2 in both directions providing an effective scale of $0.63''$ per pixel at FLWO and $0.40''$ per pixel at the VATT.

The digitized images were downloaded from the STSCI Digitized Sky Survey (http://stdatu.stsci.edu/dss/). We found that both HH 7-11 and Cep E (HH 377) appear in the First Generation Survey, as well as in the Second Generation (Red) Survey. The details of the digitized plates and the ground based observations are presented in Table 1.

3. Analysis

One needs to be careful when comparing photographic plates with CCD images. We selected the DSS plates as primary reference because of their long time baseline that allows a more accurate measurement of the small pixel shifts produced by the proper motions. The CCD images by themselves cover only a period of 7 (HH 7-11) and 4 (HH 377) years respectively, and so we use them as secondary indicators. The idea is to set the measurements of the CCD images in the same scale of the plates, and then check for consistency and/or differences between them. The reason to proceed in this way is to minimize systematic effects

that could arise from comparing the different bandpasses used in the plates and the CCD images. The digitized plates are sensitive to radiation similar to that passing through a broad band R-filter; and so for shock excited regions, like those in outflows, this means that they might include emission from collisionally excited lines such as [N II] and [O I] (so not only [S II]) as well as Hα recombination emission, that could spatially arise from very different regions.

See Figure 1

See Figure 2

Thus all the CCD images and the second epoch digitized plates were mapped into the DSS I plate scale of 1.7$''$ pixel and brought into the same reference system by using 15 stars common to all the images for HH 7-11 and 10 for Cep E, respectively. This transformation was performed using the IRAF tasks GEOMAP and GEOTRAN, which take into account relative translations, rotations, and magnifications between images. The selected reference stars do not show any indication of systematic motions, i. e. large radial velocities or proper motions, according to the data derive from SIMBAD database and other sources (e. g. Aspin, Sandell & Russell 2000; Strom, Vrba & Strom 1976). The selected stars for HH 7-11 and Cep E (HH 377) are shown in Figures 1 and 2, respectively. As in our previous projects (Lopéz et al. 1998; Noriega-Crespo et al. 1997; Reipurth et al. 1993) the proper motions were obtained by using a cross-correlation technique over small sections of a pair of images, and checked again by measuring the difference between centroids determined by fitting two-dimensional Gaussians. The uncertainty in the measurement of well-resolved bright knots is ~ 0.1 pixels, in the pixel scale of the reference frame. Although the cross-correlation technique is quite reliable, we are limited by the available knots/structure of the earliest DSS digitized images. Because of this we concentrated only on the brightest knots of the HH 7-11 system, despite the fact that the most recent CCD images show a more rich and complex structure. In the case of Cep E despite his complex structure in the near infrared, only a knot from the south lobe is optically

visible (Noriega-Crespo 1997; Devine, Reipurth & Bally 1997).

The difference between pixels as a function of epoch for the HH 7-11 knots, and Cep E (HH 377) are shown in Figures 3 and 5, respectively. The fit to these data are presented in Table 2, and correspond to that of the filled squares (Figs 3 and 5).

4. Results & Discussion

4.1. HH 7-11 System

The proper motions of the HH 7-11 outflow range from 0.015 ± 0.009 $''$/yr (HH 9) to 0.044 ± 0.007 $''$/yr (HH 11), that at a distance of 330 pc correspond to a range of tangential velocities of $\sim 26 - 73$km s^{-1} (Table 2). Except for HH 9 which has large uncertainties and may be almost stationary, the other objects are moving away from SVS 13, the driving source (Figure 4), following its characteristic arc-shaped morphology. Overall these motions are not that different from those presented by Herbig & Jones (1983) in their Figure 4. The total velocities can be estimated using the published radial velocities (Solf & Böhm 1987), with the largest value of ~ 185 km s^{-1} for HH 11, the knot closer to the SVS 13 source. HH 9 has not published radial velocity, so a lower limit is set by its proper motion.

See Figure 3

See Figure 4

The DSS proper motions are 5-14 times *lower* than those measured using molecular Hydrogen 2.12 μm images (Chrysostomou et al. 2000). For example, compared that of HH 7 of $0.41''$/yr in H_2 with the $0.024''$/yr value (but see below). Needless to say that if the atomic/ionic gas share a similar motion with the H_2 gas, then it would be very easy to detect so large shifts in the optical images. We don't believe this difference is real. We trust the optical results more than those from H_2 because of the longer time-span (nearly 37 yrs

compared with 4-5 yrs) and the larger number of well selected and measured reference stars. These two ingredients are necessary to avoid systematic offsets, magnifications and rotations that could bias the results in an unexpected fashion.

Although the shifts measured in the CCD [S II] images are consistent with the "predicted" by the DSS proper motions, in detail there are some differences, particularly for HH 7 and HH 10, as shown by the fits (dotted line) to their measurements (open circles) in Figure 3. The proper motions for HH 7 based on the CCD [S II] images are PM_x = -0.12±0.02″/yr and PM_y = 0.08±0.02 ″/yr , which corresponds to velocities of V_x = 190±20 km s^{-1} and V_y = 130±20 km $s^{-1}$for a distance of 330pc. The tangential velocity derived from them is $V_{tan} = 230 \pm 28$ km s^{-1} with a position angle PA = 56°± 7°. This velocity is 5 times faster than the mean motion obtained from the DSS plates, but it is a bit misleading since it is based *only* on the bowshock, without the Mach Disk (which do not display a shift at all), and it is biased by the lower angular resolution of the 1993 image. But even if this estimate were correct, is still a factor 2 less than that obtained for HH 7A in H_2 of 450 ± 44 km s^{-1} by Chrysostomou et al. 2000, that assumes a distance of 220pc. The case of HH 10 is less dramatic, but shows the difficulty of using only two epochs separated by a relatively short period of time, since its shift in the Y-direction has a positive slope (Fig 3, open circles). This means going from PM_y = -0.019±0.008 ″/yr to PM_y = 0.015±0.02″/yr , with a change of position angle of nearly 80°; the total tangential velocity is essentially the same as before.

Astrophysically there are at least two reasons which indicate that the smaller proper motions are more appropriated; one is the luminosity of the source and the other the low excitation of the objects. The recent interferometric maps of the HH 7-1 outflow (Bachiller et al. 2000), as well as the near infrared NICMOS images (Noriega-Crespo et al. 2000), have confirmed that a jet arises from SVS 13 and that the molecular CO gas follows the path of HH 7-11 optical knot; so there is little doubt that SVS 13 is the outflow source. SVS 13 is a relatively low mass young stellar object, with a bolometric luminosity of $\sim 85\ L_\odot$ (Molinari,

Liseau & Lorenzetti 1993), and so we do not expect outrageously high outflow velocities as seen in intermediate or high protostellar mass objects, like e.g. HH 80-81 where flow velocities of $\sim 600 - 1400$ km s^{-1} have been measured (Marti et al. 1993) or Z CMa ≥ 600 km s^{-1} (Poetzel, Mundt, & Ray 1989) with luminosities of 2×10^4 and 3500 L$_\odot$ (Marti et al. 1993; Hartmann et al. 1989). The other indicator are the shock velocities themselves, since at least at first approximation we expect high shock velocities for high flow velocities at the leading working surface. Again this is what is observed in systems like HH 1/2 or HH 80/81, where the [O III] emission confirms their higher excitation and shocks higher than 100 km s^{-1}. We do not see such high excitation in HH 7-11. The shock velocities obtained from the optical spectra for HH 7-11 are $\sim$ 40 km s^{-1} (Solf & Böhm 1987). The ISO observations in the mid/far infrared also set a limit of $\sim 40 - 50$ km s^{-1} for the shock velocities of both outflow lobes (Molinari et al. 2000), in agreement with the value derived using optical spectroscopic observations and consistent with the low excitation nature of these objects.

Finally, the optical and H_2 measurements are really sampling different gases in the case of HH 7-11, and this quite apparent from the superposition of 2.12 μm and [S II] emission. The extreme example corresponds to HH 11, that appears as a bullet even in the high angular resolution WFPC2 images (Noriega-Crespo et al. 2000), while the H_2 emission is fuzzy, wide open and a few arc seconds downstream, as what one would expect from emission arising at the wings of a bowshock.

4.2. Cep E - HH 377

For HH 377 we proceed as with HH 7-11, we use the DSS plates to determine the mean proper motions and then we analyze the shifts measured in the CCD images with the predicted values. The case for HH 377 is more simple than for HH 7-11, since we are dealing with a single optical knot. Our measurement indicate that HH 377 is moving away from the IRAS

23011+6126 source (PA = 206°±8°) with a proper motion of 0.031 ± 0.004 ″/yr (Table 2; Fig 5), that at a distance of 730pc translates into a tangential velocity of ∼ 107 km s^{-1}(Figure 6). The CCD measurements are consistent with their predicted values, although they could be higher, as indicated by the fit (dotted line) to the open squares in Figure 5, i.e. PM$_x$ = -0.068± 0.03 ″/year and PM$_y$ = -0.077± 0.03 ″/year. This corresponds to V$_{tan}$ = 230 ± 98 km s^{-1} and PA = 220°± 20°. We can estimate the flow velocity of Cep E, by combining the proper motions and the radial velocity of HH 377. Thus, if we take the DSS mean proper motion and a mean radial velocity of ~ -70 km s^{-1} obtained from Hα, [SII] 6717/31 and [O I] 6300/63 emission lines (Ayala et al. 2000), which leads to a total velocity of ∼ 130 km s^{-1}. This flow velocity is quite similar to the 125 km s^{-1}obtained from the radio measurements of the ^{12}CO(2-1) molecular gas emission (Eislöffel et al. 1996) for the blue wing of the outflow.

For Cep E (HH 377) the shock velocities range from $\sim 15 - 35$ km s^{-1} , based on optical and near/mid/far infrared spectroscopic observations (Ladd & Hodapp 1997; Ayala et al. 2000; Moro-Martin et al. 2001). The source itself, IRAS 23011+6126, a Class 0/I protostellar object has a bolometric luminosity of 30L$_\odot$, i.e. a low mass YSO (Moro-Martin et al. 2001). So the power of the source and the magnitude of the flow and shock velocities are in agreement.

5. Conclusions

We have obtained the proper motions of two semi-embedded young stellar outflows, HH 7-11 and HH 377 (Cep E) using optical images in [S II] and DSS plates epoch I and II. The HH 7-11 system has proper motions comparable in magnitude and direction as those previously obtained by Herbig & Jones (1983), but almost a factor 10 smaller than those measured for the molecular Hydrogen gas using H_2 2.12μm near infrared images.

Astrophysically is difficult to see why there should be such a large discrepancy, and so we

have argued on favor of the optical measurements based on a longer time baseline and a more accurate reference frame between the images at different epochs. If the optical measurements are correct, then this questions theoretical scenarios based on speeds exceeding 400 km s^{-1} for HH 7. Presently, however, we can not rule out ideas that explain the observed excitation in HH 7/11 as the result of a fast jet propagating through a stationary medium which contains several dense clumps or structures (Chrysostomou et al. 2000). In this context it interesting to notice that HH 9, given its proper motion, may not be part of the HH 7-11 outflow, although certainly it is a shock excited condensation. We should point out, however, that ASR 57 another shock excited clump $\sim 90''$ south-east from HH 7 seems to be related to the HH 7-11 outflow (Aspin, Sandell & Russell 2000), and might be the outcome of a previous major ejection event from SVS 13, and if so, we are not dealing necessarily with a stationary medium.

The case for HH 377 (Cep E) is more simple, and its proper motion is quite consistent with other velocity indicators, e. g. the $^{12}CO(2-1)$ outflow velocity wings, and with the overall bipolar morphology driven by IRAS 23011+6126.

See Figure 5

See Figure 6

We thank S. Curiel for making available to us his 1996 HH 7-11 optical images, to A. Moro-Martin for her careful reading of the manuscript, and last but not least, to the referee Jochen Eislöffel for his insightful comments. The Digitized Sky Surveys were produced at the Space Telescope Science Institute under U.S. Government grant NAGW-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain. The National Geographic Society - Palomar Observatory Sky Atlas (DSS-I) and the Second Palomar Observatory Sky Survey (DSS-II) were made by the California Institute of Technology.

REFERENCES

Aspin, C., Sandell, G., Russell, A.P.G. 1994, A&AS, 106, 165

Ayala, S., Noriega-Crespo, A., Garnavich, P.M. et al. 2000, AJ, 120, 909

Bachiller, R., Gueth, F., Gilloteau, S., Tafalla, M., & Dutrey, A. 2000, A&A, 362,33

Böhm, K.-H. & Solf, J. 1990, ApJ, 348, 297

Burrows, C.J., Stapelfeldt, K.R., Watson, A., Krist, J.E. et al. 1996, ApJ, 473, 437

Chrysostomou, A., Hobson, J., Davis, C.J., Smith, M.D., & Berndsen, A. 2000, MNRAS, 314, 229

Curiel, S., Raga, A., Raymond, J., Noriega-Crespo, A. & Cantó, J. 1997, AJ, 114, 2736

Devine, D., Bally, J., Reipurth, B., & Heathcote, S. 1997, AJ, 114, 2095

Eislöffel, J., & Mundt, R. 1992, A&A, 263, 292

Eislöffel, J., Mundt, R., & Böhm, K.-H. 1994, AJ, 108, 1042

Eislöffel, J., & Mundt, R. 1994, A&A, 284, 530

Eislöffel, J., Smith, M.D., Davis, C.J. & Ray, T.P. 1996, AJ, 112, 2086

Hartigan, P., Morse, J.A., Reipurth, B., Heathcote, S., & Bally, J. 2001, ApJ, 559, L157

Hartmann, L., Kenyon, S.J., Hewett, R., Edwards, S., Strom, K.M., Strom S.E., Stauffer, J.R. 1989, ApJ, 338, 1001

Heathcote, S., & Reipurth, B. 1992, AJ, 104, 2193

Herbig, G.H., & Jones, B.F. 1981, AJ, 86, 1232

Herbig, G.H., & Jones, B.F. 1983, AJ, 88, 1040

Ladd, E.F. & Hodapp, K.-W. 1997, ApJ, 474, 749

Lee, J.-K., & Burton, M.G. 2000, MNRAS, 315, 11

Lopeź, R., Rosado, M., Riera, A., Noriega-Crespo, A. et al. 1998, AJ, 116, 845

Martí, J., Rodríguez, L.F., Reipurth, B. 1993, ApJ, 416, 208

Marti, J., Rodriguez, L.F., & Reipurth, B. 1998, ApJ, 502, 337

Micono, M., Davis, C.J., Ray, T.P., Eislöffel, J., & Shetrone, M.D. 1998, ApJ, 494, L227

Molinari, S., Liseau, R., & Lorenzetti, D. 1993, A&AS, 101, 59

Molinari, S., Noriega-Crespo, A., Ceccarelli, C. et al. 2000, ApJ, 538, 698

Moro-Martin, A., Noriega-Crespo, A., Molinari, S. et al. 2001, ApJ, 555, 146

Noriega-Crespo, A. 1997 in "Herbig-Haro Flows and the Birth of Stars", IAU Sym 182, B. Reipurth & C. Bertout, 103

Noriega-Crespo, A., Garnavich, P.M., Curiel, S., Raga, A.C. & Ayala, S. 1997, ApJ, 486, L55

Noriega-Crespo, A., Cotera, A., Young, E. & Chen, H. 2000, AAS, 197, 1008

Poetzel, R., Mundt, R., & Ray, T.P. 1989, A&A, 224, L13

Pravdo, S. H., Rodriguez, L. F., Curiel, S., Cantó, J., Torrelles, J. M., Becker, R. H., & Sellgren, K. 1985, ApJ, L35

Raines, S.N., Watson, D.M., Pipher, J.L. et al. 2000, ApJ, 528, L11

Reipurth, B., Raga, A.C., & Heathcote, S. 1992, ApJ, 392, 145

Reipurth, B., Heathcote, S., Roth, M., Noriega-Crespo, A. & Raga A.C. 1993, ApJ, 408, L49

Reipurth, B., Raga, A.C., & Heathcote, S. 1996, A&A, 311, 989

Rodrıǵuez, L.F., Ho, P.T.P., Torrelles, J.M., Curiel, S., & Cantó, J. 1990, ApJ, 352, 645

Solf, J., & Böhm, K.-H. 1987, AJ, 93, 1172

Strom, S.E., Vrba, F.J., & Strom, K.M., AJ, 81, 314

This manuscript was prepared with the AAS LATEX macros v4.0.

Table 1. HH 7-11 and Cep E (HH 377) Data

Date	Band	Scale ($''$/pixel)	Telescope
HH 7-11			
10/24/1955	DSS E Red	1.70	Palomar 48in Schmidt
09/30/1992	DSS II Red IIIaF	1.00	Palomar 48in Schmidt
10/12/1993	[SII] 6717/6731 Å	0.65	Mt. Hopkins 1.2m
11/29/2000	[SII] 6717/6731 Å	0.40	VATT
Cep E			
10/31/1953	DSS E Red	1.70	Palomar 48in Schmidt
09/03/1991	DSS II Red IIIaF	1.00	Palomar 48in Schmidt
09/16/1996	[SII] 6717/6731 Å	0.65	Mt. Hopkins 1.2m
11/30/2000	[SII] 6717/6731 Å	0.40	VATT

Table 2. HH 7-11 and Cep E (HH 377) Proper Motions

Object	$PM_x(''/yr)$	$PM_y(''/yr)$	$PM_{tot}(''/yr)$	PA(°)	V_{tan}(km s^{-1})[a]
HH 7	0.022 ± 0.014	-0.007 ± 0.003	0.024 ± 0.014	108 ± 10	38 ± 23
HH 8	0.008 ± 0.001	-0.017 ± 0.005	0.019 ± 0.005	155 ± 21	30 ± 9
HH 9	-0.010 ± 0.006	0.011 ± 0.006	0.015 ± 0.009	318 ± 31	26 ± 15
HH 10	0.010 ± 0.005	-0.019 ± 0.008	0.022 ± 0.010	152 ± 50	36 ± 14
HH 11	0.039 ± 0.005	-0.020 ± 0.006	0.044 ± 0.007	117 ± 6	73 ± 12
HH 377	-0.013 ± 0.004	-0.028 ± 0.006	0.031 ± 0.004	206 ± 8	107 ± 14

[a]For distances: d(HH 7-11) = 330 pc & d(Cep E) = 730 pc

Table 3. HH 7-11 and Cep E (HH 377) Velocities

Object	V_{rad}[a,b] (km s^{-1})	V_{tan} (km s^{-1})	V_{total} (km s^{-1})	γ[c] (°)
HH 7	-51 ± 20	38 ± 23	63 ± 30	-53 ± 20
HH 8	-57 ± 20	30 ± 9	64 ± 15	-62 ± 13
HH 9	···	26 ± 15	···	···
HH 10	-35 ± 20	36 ± 14	50 ± 24	-44 ± 19
HH 11	-175 ± 20	73 ± 12	190 ± 19	-67 ± 6
HH 377	-70 ± 10	107 ± 14	128 ± 12	-33 ± 5

[a]From Solf and Böhm 1987 for HH 7, 8, 10 and 11

[b]From Ayala et al. 2000 for HH 337

[c]From $\gamma = \tan^{-1}(V_{rad}/V_{tan})$

Figure Captions

Fig. 1.— References stars for the HH 7-11 outflow in the DSS Second Generation image, J2000 coordinates and FOV = $7'$.

Fig. 2.— References stars for the Cep E (HH 377) outflow in the DSS Second Generation image, J2000 coordinates and FOV = $7'$. HH 377 lies in between reference stars 1 and 2.

Fig. 3.— The difference in pixels X-direction (left) and Y-direction (right) for the HH 7-11 images as a function of time (yrs). The filled squares correspond to the DSS measurements, while the open circles to those from [S II].

Fig. 4.— A graphic display of the tangential velocities of HH 7-11, based on the proper motion measurements.

Fig. 5.— The difference in pixels (X and Y directions) as a function of time (yrs) for the Cep E (HH 377) images. The filled squares correspond to the DSS measurements, while the open circles to those from [S II].

Fig. 6.— A graphic display of the tangential velocities of Cep E (HH 377), based on the proper motion measurements.

This figure "anc_f01.jpg" is available in "jpg" format from:

http://arXiv.org/ps/astro-ph/0109500v1